EFFECT OF PRESSURE ON THE SUPERCONDUCTOR $Cd_2Re_2O_7$*

M. Abliz[a,b], M. Hedo[a], Y. Uwatoko[a], T. Matsumoto[b]
M. Hanawa[a] and Z. Hiroi[a]

[a]Institute for Solid State Physics, University of Tokyo, Kashiwanoha
Kashiwa, Chiba 277-8581, Japan

[b]National Institute for Materials Science, Sengen 1-2-1
Tsukuba, Ibaraki 305-0047, Japan

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The pressure study of superconductivity on a pyrochlore oxide $Cd_2Re_2O_7$ has been done by using a hybrid type piston cylinder cell up to 2.7 GPa. The superconductivity transition temperatures T_c increase linearly from 1 K to 2.6 K with increasing pressure up to 2.4 GPa. The residual resistivity ρ_0 gradually increases with pressure and then suddenly increases around 2.4 GPa. We found that two step superconductivity transitions appear between 0.6 and 1.36 GPa and then disappear with increasing pressure.

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1. Introduction

The new type superconductor $Cd_2Re_2O_7$ belongs to the pyrochlore ($A_2B_2O_7$) oxide family and has transition temperature T_c about 1K [1,2]. Recently, the specific heat and other electrical properties have been studied extensively by Hiroi *et al.* [3,4]. The remarkable things of this compound are about its structure, because A and B sites possess a corner-sharing tetrahedral network of magnetic ions. Then geometrical frustrations occur in this compound, which makes an unusual ground state. So it is interesting that superconductivity could occur in such a structural frustration system. According to Sakai *et al.*, $Cd_2Re_2O_7$ is a type II superconductor with an isotropic gap [5]. Another second order phase transition occurs at $T_s = 202$ K where, however, changes from pyrochlore Fd3m to another pyrochlore F43m one [6].

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The cell volume increases slightly with decreasing temperature below T_s. So it is executable what the remarkable pressure effect on superconductivity and structural phase transitions. High Pressure (HP) study has already been done by Hiroi *et al.*, from RT to 2.3 K with pressure up to 8 GPa by using a cubic-anvil pressure cell. Unfortunately, the behaviors of superconductivity transition temperatures T_c under the pressure was not measurements under 2 K for the temperature limit of HP apparatus. In this paper, We have studied of HP effects on the superconductivity down to $T = 0.35$ K.

2. Experimental

A single crystal [3] with dimensions of $0.45 \times 0.41 \times 1.5\text{mm}^3$ was used in this studies. Sample and golden wire were adhered by using silver paste and then put it into fluorinate pressure medium in the cell. Electrical resistivity was measured by using a standard four-probe method under HP. The hydrostatic pressure of each measurement was applied at room temperature. The Ni–Cr–Al clamp cell with inner diameter 4 mmϕ was used and piston cylinder clamp cell was connected to ^{3}He cystat to get low temperature. Details of the hybrid type piston cylinder cell apparatus have been described elsewhere [8].

3. Results

The temperature dependences of electrical resistivity measured from 0.35 K to 300 K for various pressure are shown in Fig. 1(a). At 1 bar, the electrical resistivity is almost independent of the temperature, but below $T = 202$ K

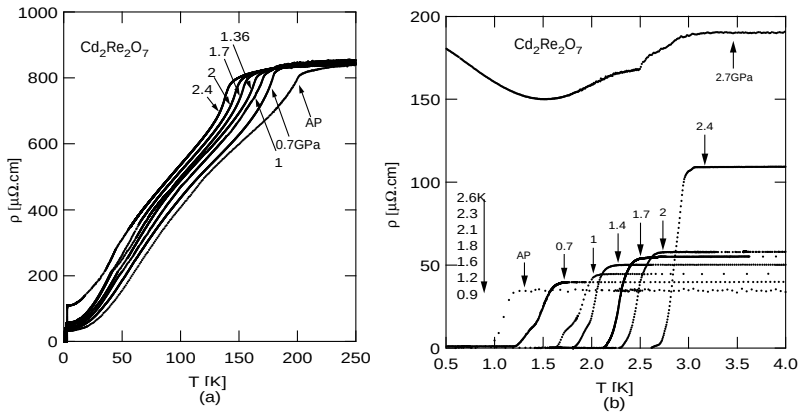

Fig. 1. Temperature dependence of resistivity of $Cd_2Re_2O_7$ for various pressure (a). Temperature dependence of resistivity of $Cd_2Re_2O_7$ in a low temperature region for various pressures (b).

suddenly decreases due to the structural phase transition. This transition are considered to make changes of electronic state of this compound which becomes good metallic below T_s [3]. According to the Harima *et al.*, band calculations, the spin–orbit interaction is mostly contribute to this phase transition, because of absence of the inversion symmetry where the structure changes from Fd3m to F43m [7]. Fig. 1(b) shows the result of resistivity for a low temperature region. The superconducting transition temperature increases from 0.9 K to 2.6 K with increasing pressure up to 2.4 GPa. The superconductivity transition temperature was defined by a offset of the resistivity in this experiment. It is remarkable result that the superconducting transition is a two steps one in this pressure regions. These two steps have been observed very clearly for between 0.6 and 1.3 GPa. The superconducting transition vanished completely under the pressure 2.7 GPa.

The residual resistivity ρ_0 difined as avalue of extrapolated to 0 K increases gradually with pressure below 2 GPa and then increases suddenly (see Fig. 2(a)). The pressure dependence of ρ_0 is consistent with the previous data of Hiroi *et al.*, [3]. It may be considered due to not only a impurity scattering but also an undistorted pyrochlore structure.

The phase diagram under pressure is shown in Fig. 2(b). The structural phase transition and superconducting transition temperatures decrease and increases linearly with increasing pressure up to 2.7 GPa and 2.4 GPa, respectively.

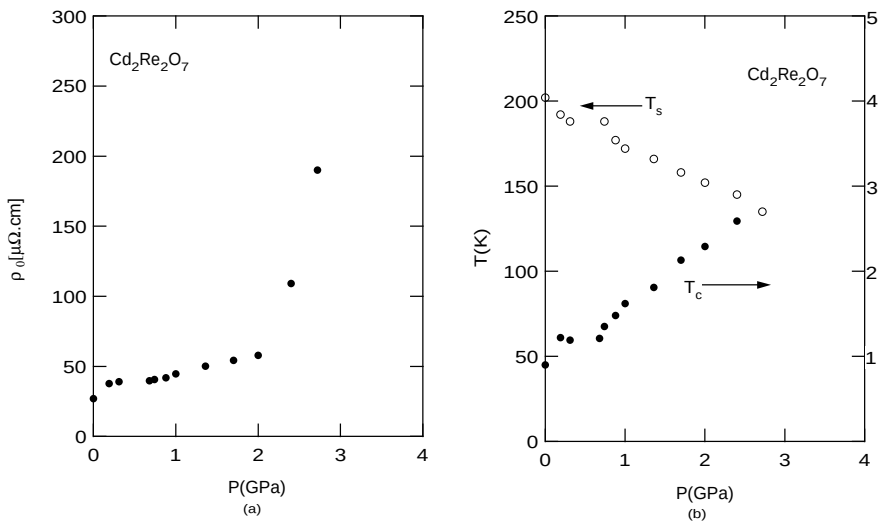

Fig. 2. Pressure dependence of residual resistivity of $Cd_2Re_2O_7$ (a), P–T phase diagram of $Cd_2Re_2O_7$ (b).

4. Discussion

The pyrochlore oxid $Cd_2Re_2O_7$ is a semi-metal for the temperature above T_s with low carrier density [7]. Below T_s, it becomes metallic under structural phase transition. It is considerable that Re^{4+} mostly contribute to conductivity below T_s. The anomalous increase of the residual resistivity indicate that charge fluctuation could be occur due to the unstability of Re^{4+} under the pressure [3]. On the other hand, increase of T_c with pressure may indicate that charge fluctuation could be control at the temperature below T_c for the pressure up to 2.4 GPa. As a result, the two-steps superconductivity phenomena, may be caused by the charge fluctuation, occur during the superconductivity transition under the pressure to 1.4 GPa.

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